JSC MATERIALS AND FRACTURE CONTROL CERTIFICATION

PROJECT/SUBSYSTEM MANAGER: Trent Martin/EA3	REF: MATL – **11** – **009**
HARDWARE NAME: Alpha Magnetic Spectrometer -02 (AMS-02) Payload Assembly	PART NUMBER: SEG39135720-304

APPLICABLE REQUIREMENTS:

Materials Requirements:

- ☒ JSC 27301F, Materials Control Plan for JSC Flight Hardware
- ☒ NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft
- ☒ NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System
- ☐ Other:

Fracture Control Requirements:

- ☐ JSC 25863B, Fracture Control Plan for JSC Space-Flight Hardware
- ☐ NASA-STD-5019, Fracture Control Requirements for Spaceflight Hardware
- ☒ Other: NASA-STD-5003, JSC 25863A

SPECIFIC ASSESSMENTS:

- ☒ Flammability
- ☒ Toxicity
- ☒ Stress Corrosion Cracking
- ☒ General Corrosion
- ☒ Fracture Control (☐ Not Applicable; Concurrence:)
- ☒ Age Life ☐ Other:
- ☒ Atomic Oxygen/Ultraviolet
- ☒ Thermal Vacuum Stability
- ☒ Fluid Compatibility: See fluid compatibility assessment in Attachment 1
- ☒ Microbiological Resistance

LOCATION:

- ☐ Orbiter Crew Cabin ☐ Spacehab ☐ ATV ☐ HTV
- ☒ Orbiter Payload Bay ☐ MPLM ☒ Space Station: ☐ Internal ☒ External
- ☐ Progress ☐ Soyuz ☐ Other:

MATERIALS USAGE AGREEMENTS (MUAs):

- ☐ No MUAs
- ☒ MUA Number(s): PI 217, AG 577, ISS-256, and ISS-257 for SCC; ISS-255 for AO/VUV and Use Temp Range.
  Deviation: SCC, AO/VUV and Use Temperature Range

LIMITATIONS: ☒ No Limitations

- ☐ Materials:
- ☐ Fracture Control:

This JSC Materials and Fracture Control Certification is consistent with existing Materials or Fracture Control Reciprocal Agreements. Materials Certification to JSC 27301 or NASA-STD-6016 and Fracture Control Certifications to JSC 25863 or NASA-STD-5019 comply with applicable materials and processes and fracture control requirements in the following program-specific documents: SE-R-0006D, Space Shuttle System Requirements for Materials and Processes; SSP 30233G, Space Station Requirements for Materials and Processes; NASA-STD-5003, Fracture Control Requirements for Payloads Using the Space Shuttle; SSP 30558C, Fracture Control Requirements for Space Station; SSP 52005B, ISS Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures.

APPROVALS

Fracture Control Manager, S. Forth	Date	GFE Materials Control Manager, M. Pedley	Date
	12/10/10	M. D. Pedley	12/8/10

ATTACHMENT 1

Hardware Acceptance Summary Report for Materials

Hardware Descriptions

The Alpha Magnetic Spectrometer -02 (AMS-02) payload is designed to measure the cosmic rays spectrum and their charge, momentum, and velocity in space. It will be attached to ISS S3 Zenith Inboard Payload Attachment System (PAS). It uses a Neodymium-Iron-Boron (Nd-Fe-B) permanent magnet and several high energy particle detector systems to collect cosmic ray data.

The AMS-02 payload consists of the AMS-02 experiment hardware provided by the International AMS Collaborators and the AMS-02 payload integration hardware provided by the National Aeronautics and Space Administration (NASA). The AMS-02 experiment hardware will be certified to meet the materials safety requirements of NSTS 1700.7B only. The NASA provided Government-Furnished Equipment for the AMS-02 payload integration will be certified to meet NSTS 1700.7B, JSC 27301F, and NASA-STD-6016. This certification only covers the AMS-02 payload mounted in the Orbiter payload bay and ISS external structure. The Shuttle Digital Data Recording System (DDRS) was certified on MATL-09-036 and ISS DDRS was certified on MATL-10-065A.

The AMS experiment hardware provided by Massachusetts Institute of Technology (MIT) and International Collaborators include the Permanent Magnet System, Transition Radiation Detector (TRD), TRD Gas System, Upper and Lower Time-Of-Flight (TOF) Scintillator Assembly, AMS-02 Silicon Tracker Assembly, Tracker Plane 1N, Tracker Plane 6, Tracker Alignment System (TAS), Anti-Coincidence Counters (ACC), Ring Imaging Cerenkov Counter (RICH), Electromagnetic Calorimeter (ECAL), Thermal Control System (TCS), thermal blankets, Global Positioning System (GPS) Receiver and antenna, and Star Tracker.

The AMS-02 payload integration hardware include the previously certified Shuttle and ISS hardware, Vacuum Case (VC), Micrometeoroid and Orbital Debris (MMOD) Shields, Payload Attach System (PAS), EVA Interface Panel, Interface Panel A, Shuttle and ISS DDRS and associated cables, power and data cables from interface panels to various electrical boxes, J-Crate, and Power Distribution System (PDS), thermal blankets, and Unique Support Structure-02 (USS-02).

Permanent Magnet (PM):
In the AMS-02 experiment, the PM provides the magnetic field to bend the trajectories of incoming electrically charged particles. The particle trajectories are recorded by the AMS high energy particle detector system for search of anti-matter and dark matter in space. The PM is constructed of neodymium-iron-boron (Nd-Fe-B) magnets arranged in a cylindrical structure and capable of producing a uniform 1400 Gauss field in the interior bore. The same Nd-Fe-B PM was used on AMS-01flown on STS-91. It was refurbished and its structural integrity was verified to be acceptable for AMS-02. No signs of corrosion and structural damage were found. The closeout weld was re-inspected and no flaws/cracks were found. All accessible fasteners were removed and replaced with new fasteners provided by NASA/JSC. The epoxy adhesives used in the PM are J-39 (Material Code: 03493) and FA-56/BA99 (Material Code: 03500). The J-39 adhesive was used to bond the individual blocks of magnetic material to each other. The FA-56/BA99 adhesive was used to fill in all the interior spaces of the magnet casing and completely encapsulate the magnet blocks and J-39 joints. The adhesives are sealed inside the magnet casing to prevent any outgassing issue. The degradation of the epoxy adhesives over time will not affect the structural integrity of the PM because its structural integrity was qualified without the adhesives. The PM is supported inside the VC by the Double X (DX) 7075-T7351 Al alloy structure and sixteen Ti-6Al-4V support struts. The upper and lower flanges of the PM are bolted to the upper and lower conical flanges of the VC.

Transition Radiation Detector (TRD):
The TRD detector comprises 5248 proportional tubes (straws) which are made from a multi-layer wound composite structure. The composite includes layers of polyurethane, carbon-polyimide, aluminum, and Kapton. The TRD is constructed from 20 layers of straw modules where a gap of 0.91 inch between the layers is filled with a radiator material (LRP 375 BK, polyethylene/polypropylene fleece). A straw module consists of 16 straws bonded together with 6 stiffeners running alongside the straws using EA934NA adhesive. The straw ends are bonded into polycarbonate end pieces with EA934NA adhesive. The end pieces contain the wire fixation pieces, the gas distributor, and the gas seal. The 20 layers of straw modules and radiators are mounted in an octagon structure, which consists of 8 honeycomb side panels (1.18" thick, carbon fiber skin/ Al 5056 honeycomb), a lower honeycomb support plate (carbon fiber skin/ Al 5056 honeycomb), and upper honeycomb support plate (carbon fiber skin/ Al 5056 honeycomb). The straw modules will be filled with a Xenon (Xe)/CO2 (80:20) mixture to detect Transition Radiation (TR) photons generated inside the radiator material. The TRD M-structure, corner brackets, and upper brackets are made of 7075-T7351 Al alloy.

The TRD Gas Supply System supplies a mixture of 80% Xe and 20% CO2 to the straw modules of TRD detector. The TRD gas supply system includes three tanks: one Xe tank, one CO2 tank, and one mixing tank. These tanks are mounted to a support bracket and covered by a Micrometeorites and Orbital Debris (MMOD) shield. The support bracket is mounted to the wake side of the USS-02. The fittings, tubing, connections, manifolds in the gas supply system are made of CRES 316/CRES 304. Other structural parts include 7050-T7451 box S plate and lower bracket, and 6061-T6 Xe tank bracket, box C base plate, and valve bracket. The Xe and CO2 tanks are made of the carbon fiber Composite Overwrapped CRES 301pressure vessels. The mixing tank is made of CRES 321 cylinder and CRES 304L dome.

Time-Of-Flight (TOF) Scintillator Assembly:
The TOF scintillator counters comprise four planes of detectors: two atop the AMS tracker core, and two below. Planes 1, 2, and 4 have eight detector paddles per plane and Plane3 has ten detector paddles. Each detector paddle made of polyvinyl toluene is enclosed in a cover made of carbon fiber. At the end of each paddle are Lucite light guides, which direct the light of scintillation to photo multipliers. The TOF measures the particle trajectory and the absolute charge of the particle when a particle crosses the bore of PM and Silicon Tracker. The upper TOF honeycomb (2024-T81skin/5052 core) structure attaches to the TRD corner joints via 7075-T7351 brackets. The lower TOF honeycomb structure attaches to the lower USS-02 via 7075-T7351 struts. Non-metallic materials used include Plexiglass for light guides, Araldite AV138, CV1146, and CV1152 for adhesives and conformal coating, and DC93-500 for potting/encapsulant.

Anti-Coincidence Counters (ACC), Ring Imaging Cerenkov Counter (RICH), Electromagnetic Calorimeter (ECAL):
The ACC comprises sixteen interlocking scintillating panels that are between the Silicon Tracker shell and the PM. The ACC detects and identifies particles that enters or exits the Trackers through the side or that have not cleanly traversed the Tracker. The panels fabricated from BICRON BC414 are supported by a M40J/CE Carbon Fiber Composite (CFC) support cylinder.

The RICH is used to measure the velocity of the particles that traverse the AMS-02. The materials used in RICH include 7075-T7351, 6061-T651, CRES A286, 304, 316, 15-5PH H1025, EX15115 cyanate ester/graphite for reflector, Vacoflux 50 Co-Fe alloy and ARMCO soft iron for PMT shielding, silica aerogel, and Sodium Fluorite, CV1152 silicone, AV138, and 2216 epoxy adhesives.

The ECAL is a fine grained lead-scintillating fiber sampling calorimeter. It measures the energy of electrons, positrons, and gamma rays up to 1Tera Electron Volt (TeV). The major materials used in ECAL include 2014-T6 I-beam and side panel, 2024-T4 face plate, 7050-T7451 bracket and support beam. Non-metallic materials used include Acrylic (PMMA) light guides, polycarbonate Photo Multiplier Tube (PMT) support, DC93-500 potting compound, Therm-A-gap A274, and T274 silicone elastomer.

Unique Support Structure-02 (USS-02):
The USS-02 is the primary structural element of the AMS-02 payload. It supports the PM and the AMS-02 experiment hardware during launch, landing, and on-orbit loading, and integrates them with Shuttle and ISS. The USS-02 consists of five primary subassemblies- the upper USS-02, Vacuum Case (VC), lower USS-02, Keel, and PAS. Metallic materials used in upper and lower USS-02 include Custom 455 H1000, 7050-T7451, 7075-T73411, and 6061-T6511. Metallic materials used in VC include CRES A286, 7050-T7451 plate, 2219-T62 conical flange, 7050-T7451 rolled ring forging, and 7050-T7452 rolled ring forging. Metallic materials used in PAS include 7050-T7451, CRES 15-5PH H1025, and CRES A286.

SPECIFIC MATERIALS ASSESSMENTS

Stress Corrosion Cracking (SCC):
Many non-Table I materials for SCC were used for major structural components of both AMS payload integration hardware and AMS experiment hardware. The non-Table I materials used in the payload integration hardware include Al alloy 7050-T7452 rolled ring forging for the outer cylinder, lower support ring, and upper support ring of vacuum case assembly, Al alloy 7050-T7451 interface plates of vacuum case assembly, Al alloy 7050-T7451 structural parts of lower and upper USS, Al alloy 7050-T7451 guide pins, aft and vertex brackets, bridge, and platform of Payload Attach System (PAS), Al alloy 7050-T7451 clevis, Payload Disconnect Assembly (PDA) mounting bracket, PDA harness bracket of Remotely Operated Electrical Umbilical (ROEU). The non-Table I materials used in the AMS-02 experiment hardware include the Al alloy 7050-T7451 bracket and support, Al alloy 2014-T6 I-frame and side panel, and Al alloy 2024-T4 face plate of Electromagnetic Calorimeter (ECAL), and Al alloy 7050-T7451 plate and brackets of TRD Gas Supply System. The acceptance rationale for the use of these non-Table I materials are documented in the following NASA MUAs:

- AG 577, 7050-T7451/T7452 Parts in USS, VC, PAS, and ROEU of AMS-02
- ISS-256, Electromagnetic Calorimeter (ECAL), AMS-02
- ISS-257, Al 7050-T7451Parts in Transition Radiation Detector (TRD) Gas Supply System, AMS-02

Al alloy 7175-T7351used in some structural parts of AMS-02 Thermal Control System (TCS) and Power Distribution System (PDS) is not listed in Table I materials for SCC in MSFC-STD-3029, Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments. Test specimens of 7175-T7351 Al alloy were tested for SCC. As a result of the SCC testing, 7175-T7351 Al alloy was classified as Table I material for SCC. The SCC test results are documented in AMS02-RA-CGS-001, which is part of the ISS MUA#PI 217 (Utilization of Aluminum Alloy 7175-T7351).

All other metallic structural parts are made of Table I materials for SCC.

General Corrosion:
The metallic materials used in the NASA-provided payload integration hardware were evaluated for general corrosion and found acceptable. Complete verification of acceptable corrosion protection finishes on metallic parts of some AMS experiment hardware is not possible because of incomplete paperwork/traceability and missing drawings. However, the International Collaborators followed the same AMS-02 corrosion control plan for their hardware and consulted with the Materials Engineers in the AMS-02 Project team. Furthermore, the AMS-02 experiment hardware is stored in a controlled laboratory environment, protected from moisture during transportation on the ground, and used in space vacuum. General corrosion is not expected to be an issue with the AMS-02 experiment hardware.

Flammability:
The AMS-02 payload has no flammable exposed surfaces. Most of the exterior surfaces of the AMS-02 payload are covered with 1) MLI blankets with a non-flammable outer layer of Teflon-coated beta-cloth, 2) non-flammable silver Teflon tape, and 3) non-flammable SG121FD white paint. The 0.015" thick Lexan 8A13-112 film used for the STS134 decal (10" W x 10" L) on the Starboard Debris Shield, and the AMS-02 logo decals (26"W x 35" L, 19"W x 26" L) on the Port and Starboard Debris Shields passed the flammability test in 20.9% oxygen (Reference: WSTF# 10-44147). The aluminum foil covered part of the 1N tracker plane for Atomic Oxygen (AO) protection is not flammable.

The external electrical and optical wiring/cables have either non-flammable Teflon insulation or covered with non-flammable Teflon tape or Permacel 213 glass-cloth tape. There are no ignition sources for flammability because the AMS-02 payload is powered off for launch and all entry phases. The fire hazard of ammonia leakage from the AMS-02 thermal control system in the payload bay has been evaluated. The total amount of ammonia in the AMS-02 thermal control system is 1377.8 grams. The leakage of 1377.8 grams (3.03 lbs) of ammonia in the payload bay will not form a flammable gas mixture to support a fire (Reference: ESCG-4480-09-MAAN-MEMO-0039). The flammability of the AMS-02 payload in the payload bay is not an issue.

Toxicity:
Offgassing toxicity in the open environment of payload bay is not an issue.

Aging:
The NASA-provided payload integration hardware was evaluated for aging and found acceptable. The external MLI blanket, the silver Teflon tape/3M 966 adhesive, and SG121FD silicone paint used for the passive thermal control system will have acceptable material degradation for 10 years. This certification does not cover the age life of AMS experiment hardware. The International Collaborators are responsible for the age life of their hardware.

Atomic Oxygen/Vacuum Ultraviolet (AO/VUV):
Except for the Teflon-coated Beta cloth, 5 mil thick silver Teflon tape, aluminum foil, SG121FD white silicone paint, Teflon wire insulation, Lexan 8A13-112 decal, and Permacel 213 glass cloth tape, all non-metallic materials are protected from AO exposure. The Teflon-coated Beta cloth, 5 mil thick silver Teflon tape, aluminum foil, SG121FD white silicone paint, Teflon wire insulation, Scotch 79 glass cloth tape, and Permacel 213 glass cloth tape have acceptable AO resistance based on past flight experience. The Lexan 8A13-112 decal does not contain any UV stabilizer additive and is not protected by any AO resistant coating. The Lexan 8A13-112 decal is expected to become illegible soon after exposure to the on-orbit environment because of AO erosion of the Lexan surface and color changes (bleaching) due to VUV exposure. Since the legibility of the Lexan decals is not a safety issue, the Project has accepted the consequence of Lexan decal degradation (Reference: ESCG\ISS-255).

Thermal Vacuum Stability (TVS):
All exposed materials on the external surfaces of the AMS-02 payload are "A" rated for thermal vacuum stability. These materials include the Teflon-coated Beta cloth, silver Teflon tape, SG121FD white silicone paint, Teflon wire insulation, Lexan 8A13-112, Tefzel cable tie, Scotch 79 glass cloth tape, and Pamacel 213 glass cloth tape. The AMS-02 payload meets the materials and processes requirements for outgassing in SSP30233 (Total Mass Loss (TML) < 1.0% and Collected Volatile Condensable Materials (CVCM) <0.1%). However, the overall external contamination impact of the AMS-02 payload is the responsibility of the ISS Space Environments Team and is not covered by this certification. A list of major exposed materials along with their outgassing test data per ASTM E595 and the outgassing rate data per ASTM E1559 if available have been provided to the ISS Space Environments Team for the outgassing contamination analysis of AMS-02 payload.

Fluid Compatibility:
Anhydrous ammonia and Carbon Dioxide (CO2) are used as heat transfer fluids for the AMS-02 thermal control system. Xenon and CO2 gasses are used to provide a mixture of 80% Xenon (Xe)/20% CO2 for use in the TRD straw tubes. The 6063-T5 heat pipes used in the main and track radiators and other components of the AMS-02 thermal control system are compatible with the anhydrous ammonia refrigerant. The wetted CRES 316L line, CRES 304L pump, Al alloy 6061 condenser, CRES 316LN accumulator are compatible with the CO2 cooling fluid in the Tracker Thermal Control System (TTCS). The carbon fiber composite overwrapped CRES 301tanks are compatible with the Xenon and CO2 gases. The mixing tank made of CRES 321 cylinder and CRES 304L dome is compatible with the 80% Xenon/20% CO2 gas mixture. The compatibility of anhydrous ammonia, carbon dioxide, Xenon gas, and Xe/CO2 mix gas with the wetted components of the AMS-02 payload has been evaluated and found acceptable.

Microbiological Resistance:
The AMS-02 payload was evaluated for fungus resistance and found acceptable based on its accessibility for cleaning and its use environment in space vacuum.

Conclusion

The AMS-02 payload meets the materials safety requirements of NSTS 1700.7B and is safe to fly for 10 years on ISS.

AMS-02 Final Configuration